WAVELENGTH MULTIPLEX LIGHT SOLITON TRANSMISSION SYSTEM AND TRANSMITTER

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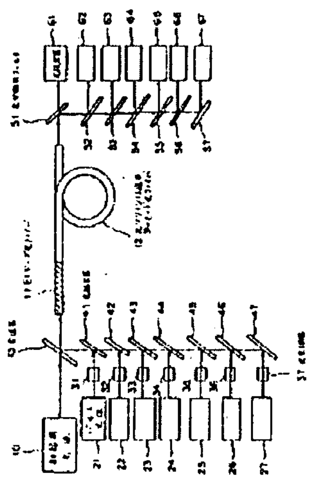
Abstract of **JP2264227**

PURPOSE:To amplify a wavelength multiplex soliton pulse train at a time and to send it over a long distance by interposing an erbium optical fiber amplifier which excites by a semiconductor layer with specific oscillation wavelength into a transmission line. CONSTITUTION:A single-mode optical fiber which is formed by doping erbium is excited by laser light with 1.4 - 1.5mum wavelength and plural signal light beams which are inputted to the erbium-doped single-mode optical fiber 11 and has mutually different wavelength of 1.53 - 1.60mum are amplified at the same time. Then the signal light beams are inputted to the single-mode optical fiber 12 for transmission as the wavelength multiplex soliton pulse train and propagated in the single-mode optical fiber 12 for transmission, and the train is regenerated and repeated. Thus, a semiconductor laser which outputs light with optional wavelength in the wavelength range can be obtained. Consequently, optical soliton is wavelength-multiplexed and transmitted over a long distance and the amount of information which can be transmitted can be increased.



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㊿発明の名称　波長多重光ソリトン伝送方式および伝送装置

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明　細　書

1．発明の名称

波長多重光ソリトン伝送方式および伝送装置

2．特許請求の範囲

1）エルビウムをドープした単一モード光ファイバを波長1.4～1.5 μm のレーザ光で励振し、該エルビウムドープ単一モード光ファイバに入力されたそれぞれ1.53～1.60μm の波長を有し、かつ互いに波長の異なる複数の信号光を同時に増幅し、波長多重光ソリトン列として伝送用単一モード光ファイバに入力して該伝送用単一モード光ファイバ内を伝播せしめ、かつ再生中継を行うことを特徴とする波長多重光ソリトン伝送方式。

2）発振波長がそれぞれ1.53～1.60μm の範囲内にあり、かつ互いに異なる複数のDFB 半導体レーザの出力光を高速変調またはモード同期して、トランスフォームリミットな波長多重光パルスを前記信号光として前記エルビウムドープ単一モード光ファイバに入力して光ソリトンのパワーレベルまで増幅し、再生中継することを特徴とする請求項1に記載の波長多重光ソリトン伝送方式。

3）エルビウムをドープした単一モード光ファイバと、

該エルビウムドープ光ファイバを励振するための1.4 ～1.5 μm の波長の光を出力する励起光源と、

それぞれ1.53～1.60μm の波長を有し、かつ互いに波長の異なる複数の信号光を前記エルビウムドープ単一モード光ファイバに入力する手段とを具えたことを特徴とする波長多重光ソリトン伝送装置。

（以下余白）

度の帯域であるため、第4図で示したような5nm間隔の波長多重の場合には、4波多重が限界であり、波長多重光ソリトン伝送のメリットを充分に生かすことは困難であった。

[発明が解決しようとする課題]

このように従来の技術は、装置の構成および取扱いが複雑で、小型化が困難であった。さらに波長多重化に際して、大きな励起入力を必要とするばかりでなく、多重度が低いという欠点があった。

本発明の目的は光ソリトンの伝送方式において、従来高い励起入力が必要とされていた誘導ラマン散乱によるソリトン増幅に比較して低い励起入力で波長多重された光ソリトンパルス信号を同時に増幅し、波長多重された複数ソリトンを安定に再生中継する光ソリトン伝送方式およびそのための装置を実現することにある。

[課題を解決するための手段]

本発明方式は、エルビウムをドープした単一モード光ファイバを波長1.4 ～1.5 μm のレーザ光で励振し、エルビウムドープ単一モード光ファイバに入力されたそれぞれ1.53～1.60μm の波長を有し、かつ互いに波長の異なる複数の信号光を同時に増幅し、波長多重光ソリトン列として伝送用単一モード光ファイバに入力して伝送用単一モード光ファイバ内を伝播せしめ、かつ再生中継を行うことを特徴とする。

ここで、発振波長がそれぞれ1.53～1.60μm の範囲内にあり、かつ互いに異なる複数のDFB 半導体レーザの出力光を高速変調またはモード同期して、トランスフォームリミットな波長多重光パルスを信号光としてエルビウムドープ単一モード光ファイバに入力して光ソリトンのパワーレベルまで増幅し、再生中継する方式であってもよい。

本発明装置は、エルビウムをドープした単一モード光ファイバと、エルビウムドープ光ファイバを励振するための1.4 ～1.5 μm の波長の光を出力する励起光源と、それぞれ1.53～1.60μm の波長を有し、かつ互いに波長の異なる複数の信号光をエルビウムドープ単一モード光ファイバに入力する手段とを具えたことを特徴とする。

[作　用]

本発明においては波長1.40～1.50μm の半導体レーザ光によりErファイバ増幅器を励振し、波長1.530 ～1.560 μm の複数波長の光ソリトンを同時に増幅再生し、波長多重光ソリトン伝送を実現する。従来の誘導ラマン散乱による増幅方法は光ファイバ中の非線形光学効果を用いているが、本発明は光ファイバのコア部にErをドープし、波長1.53～1.56μm の帯域幅内で光ソリトンを増幅できるレーザ媒質をあらかじめ形成しておく点が本質的に異なる。誘導ラマン散乱を用いたソリトン増幅にはファイバ長が10～30km程度必要であるが、Erファイバ光増幅器の場合には数mの長さで10dB以上の利得が得られる点も大きな差である。また、誘導ラマン散乱による増幅の場合には増幅度を5dB 程度得ようとすると、光損失の小さい細径スポットサイズのファイバを用いる必要があり、加えて200mW 以上の大励起入力が必要となる。しかしErファイバ増幅器を用いると100mW 以下の低い励起入力で10dB程度の高い利得が得られる。

誘導ラマン散乱では、波長1.46μm 帯励起の場合1.55μm を中心に20nm程度の帯域であるが、本発明ではErファイバ増幅器を用いているので帯域が40nmと広いため、波長多重光ソリトン通信が可能となる。

[実施例]

以下に図面を参照して本発明の実施例を説明する。

<u>実施例1</u>

第1図は本発明の第1の実施例を説明する図である。第1図において、10はEr光ファイバ増幅器励起用光源、21,22,23,24,25,26 および27はそれぞれ波長1.530,1.535,1.540,1.545,1.550,1.555

これを動作するには、DFB レーザ81〜87を連続波発振動作させ、この出力を光変調器31〜37で高速変調する。光変調器としては例えば$LiNbO_3$を用いたマッハ・ツェンダ型導波路型変調器を用いる。これらの変調信号および励起光を光ファイバカップラ71〜77で合波し、Er光ファイバ増幅器11に結合し、信号光パルスを光ソリトンの領域となる振幅まで増幅する。

合波器として光ファイバカップラを使うことにより、各光ファイバカップラを構成する光ファイバの先端を融着接続することによって波長多重を実現できる。これにより、半透過鏡とダイクロイックミラーを用いる場合に比べ、レンズなどの結合用光部品の挿入損失を大幅に減らすことができる。その結果、Er光ファイバ増幅器11の増幅度をあまり高くする必要がなく、比較的低励起入力で光ソリトンを単一モード光ファイバ12中を伝播させることができる。また、DFB レーザと外部変調器を組合わせることにより、トランスフォームリミットなパルスを得ることができるため、パルスを長距離伝播させた時の波形劣下を抑えることが可能となる。従って、光ソリトン伝送用光ファイバ12の損失を補償するようにEr光ファイバ増幅器を用いることにより、長距離にわたり波長多重光ソリトンの伝送が可能である。

実施例3

第3図は本発明の第3の実施例を説明するブロック図である。第1の実施例と同じものには同一の参照番号で示した。91〜97はモード同期DFB レーザであり、発振波長はそれぞれ1.530,1.535,1.540,1.545,1.550,1.555 および1.560 μm である。DFB レーザのモード同期は、例えばレーザに外部共振器を取り付け、共振器内に置いた光変調器を用いることにより実現できる。モード同期DFB レーザ91〜97からは、パルスの繰返し同期が共振器長で決まるトランスフォームリミットなパルス列が発生する。このパルス列を光変調器31〜37で変調し、信号パルス列を作る。これらの変調信号光およびErファイバ励起用レーザ光を光ファイバカップラ81〜87で合波し、Er光ファイバ11に結合し、信号光パルスを光ソリトンの領域となる振幅まで増幅する。

モード同期を用いることによりトランスフォームリミットなパルス列が容易に発生できるため、Er光ファイバ増幅器11を、例えば30km毎に設置し、光ソリトン伝送用光ファイバ12の光損失を補償することにより波長多重ソリトンを1000km以上の長距離にわたり伝送することができる。

[発明の効果]

以上説明したように、本発明は波長1.4 〜1.5 μm に発振波長を有する半導体レーザで励振を行うEr光ファイバ増幅器を伝送路中に挿入することにより、波長多重化したソリトンパルス列を一括して増幅し、長距離にわたって伝送することができるという利点がある。また、本光ファイバ増幅器は、比較的小出力の半導体レーザを励起に用い、増幅用光ファイバ内に反転分布をつくり増幅を行うという原理にもとづき、さらに1.53〜1.56μm の波長範囲で利得をもつため、高利得で小型、かつ広波長域の増幅器を実現できるという利点を有する。本発明により、数百Gb/s以上の超高速光通信が実現できる。

4．図面の簡単な説明

第1図は本発明の伝送方式および装置の第1の実施例を説明するブロック図、

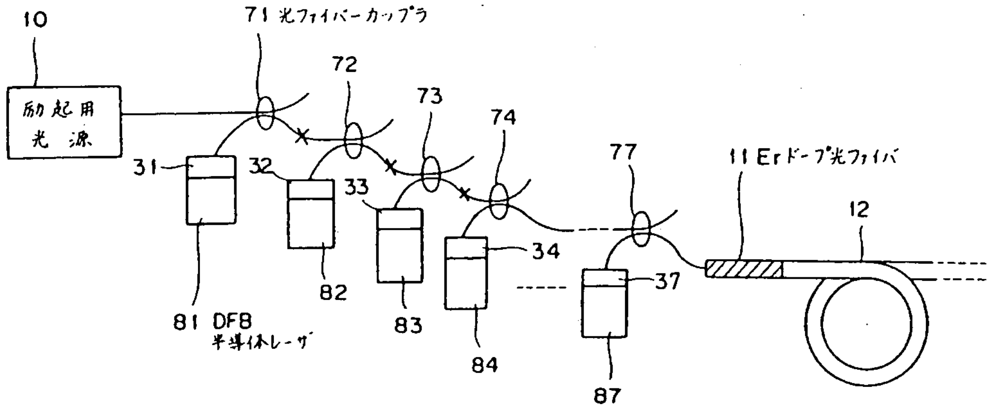
第2図は本発明の第2の実施例を説明するブロック図、

第3図は本発明の第3の実施例を説明するブロック図、

第4図は従来の光ソリトン伝送方式を説明するブロック図、

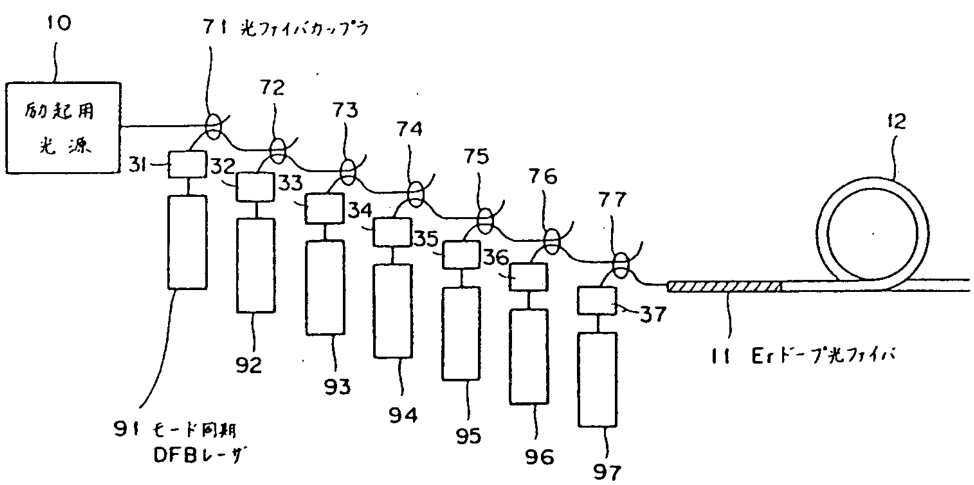
第5図は誘導ラマン散乱を用いた光増幅の方法を説明するブロック図である。

10…Er光ファイバ増幅器励起用光源、
11…光ソリトン増幅用Erドープ光ファイバ、
12…光ソリトン伝送用単一モード光ファイバ、
13…合波器、



第2の実施例のブロック図

第 2 図



第3の実施例のブロック図

第 3 図

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Job No.: 6087-114334 Ref.: : LCNT/124225JP; Lucent Case: A. R. Chraplyvy 28-3-1-7-Japan
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WAVELENGTH-MULTIPLEXED LIGHT SOLITON TRANSMISSION SYSTEM AND TRANSMITTER

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[There are no amendments to this patent.]

Claims

1. A wavelength-multiplexed light soliton transmission system characterized in that an erbium-doped single-mode optical fiber doped with erbium is excited with laser light at a wavelength of 1.4-1.5, multiple light signals that each have a wavelength of 1.53-1.60 μm, which are of different wavelengths from each other and are input to said Er-doped single-mode optical fiber are amplified simultaneously, they are input as a wavelength-multiplexed light soliton pulse train to a single-mode optical fiber for transmission to be transmitted in said single-mode optical fiber for transmission, and are regenerated and repeated.

2. The wavelength-multiplexed light soliton transmission system described in Claim 1 characterized in that the oscillation wavelengths are all in a range of 1.53-1.60 μm, the output light from multiple DFB semiconductor lasers different from each other is high-speed modulated or mode matched, and transform-limited wavelength-multiplexed light pulses are input as the aforementioned light signals to the aforementioned Er-doped single-mode optical fiber and amplified to the light soliton power level and are regenerated and repeated.

3. A wavelength-multiplexed light soliton transmitter characterized in that it comprises an erbium-doped single-mode optical fiber,

an excitation light source that outputs light at a wavelength of 1.4-1.5 μm to excite said erbium-doped optical fiber,

and a means whereby multiple light signals each having a unique wavelength between 1.53 and 1.60 μm are input to the aforementioned erbium-doped single-mode optical fiber.

Detailed explanation of the invention

Industrial application field

The present invention relates to a wavelength-multiplexed soliton transmission system and device that are small and have high gain. It particular, it relates to a wavelength-multiplexed soliton transmission system and a device therefor that use an erbium (Er) optical fiber light amplifier.

Prior art

Methods of increasing the transmission capacity of a light soliton transmission system include (1) a method to increase the bit rate and (2) a method to perform wavelength-multiplexed transmission. The method in (1) is a method whereby the light soliton pulse width is narrowed and the repetition cycle of the pulse train is shortened. However, because solitons propagate in optical fibers, the required pulse amplitude is inversely proportional to the square of the pulse width, so that in order to transmit a light soliton whose pulse width has been made 1/10, a pulse train having 100-fold increase in amplitude must be transmitted. For example, in order to propagate a light pulse of wavelength 1.55 μm with pulse width 1 ps in an optical fiber with a group velocity dispersion of -5 ps/km/mm and an effective surface area of 4×10^{-11} m^2 to give a light soliton, 6.1 W of peak power are required. This much power is very difficult to obtain with ordinary semiconductor lasers, even when high-speed modulation to this extent is possible. While a pulse with the required peak power can be realized with a color center laser, configuring and adjusting the system is complicated and miniaturization is very difficult, so that it has been unsuited to realizing an actual soliton light communication system.

The method in (2) is a method that achieves expanded information transmission capacity with wavelength multiplexing with the information transmission speed per wavelength left unchanged. Figure 4 is a block diagram that explains a conventional wavelength-multiplexed soliton transmission system. (21)-(27) are pulsed light sources for generating light solitons at wavelengths of 1530, 1535, 1540, 1545, 1550, 1555 and 1560 μm, respectively; (31)-(37) are optical modulators for optical transmission corresponding to each of the wavelengths; (41)-(47) are optical couplers for multiplexing light signals at the respective wavelengths; (12) is a single-mode optical fiber for light soliton transmission; (51)-(57) are filters that pass only the wavelengths of their respective light signals; and (61)-(67) are optical sensors. For the light soliton pulse at each wavelength, light from pulsed light sources (21)-(27) is modulated by optical modulators (31)-(37), multiplexed and coupled to optical fiber (12) by multiplexers (41)-(47) for soliton transmission. In this case, the output of optical pulsed light sources (21)-(27) must be adjusted so that the amplitude of the pulses at each wavelength in optical fiber (12) for soliton transmission will be sufficient to generate light solitons. The output of optical fiber (12) for light soliton transmission is divided into individual wavelength components by wavelength selection filters (51)-(57) and is sensed by optical sensors (61)-(67). Because of optical losses from optical fiber (12) for light soliton transmission, a repeater must be inserted before the light soliton waveforms break down. With the conventional constitution of repeaters that include electro-optical and opto-electric converters, an electrical waveform-shaping circuit, an optical sensor, a modulator, and a light source for each wavelength are required for each repeater, and a multiplexer and a branching filter are also required to synthesize and separate each wave

component. This has the disadvantage of making the repeater more complex. Therefore, the distinctive feature of solitons, i.e., that waveform reshaping and relaying are possible with only light amplification, has not been fully exploited.

A light amplification method using inductive Raman scattering has been proposed by Hasegawa of Bell Labs to transmit light solitons over long distances (A. Hasegawa, Appl. Opt., Vol. 23, page 3302 (1984)). This is a method, as shown in Figure 5, in which a soliton pulse in the 1.55 μm wavelength band attenuated in optical fiber (12) for light soliton transmission and excitation light output from excitation light source (14) in the 1.46 μm wavelength band are multiplexed by multiplexer (13), the soliton pulse is amplified by an inductive Raman scattering effect in Raman amplifying optical fiber (15), and light soliton transmission over long distances is effected by reshaping the light soliton waveform. An amplifying optical fiber (15) that is 10-30 km is required for soliton amplification using inductive Raman scattering. Additionally, to obtain a gain of around 5 dB, low loss optical fiber with small spot size is required as amplifying optical fiber (15), and large excitation input of 200 mW or more is required. The gain-bandwidth of inductive Raman scattering is a band of around 20 nm centered at 1.55 μm when the excitation wavelength is 1.46 μm, so that in the case of wavelength multiplexing at 5 nm intervals as shown in Figure 4, 4-wave multiplexing is the limit, and fully exploiting the advantages of wavelength multiplexed light soliton transmission has been difficult.

Problems to be solved by the invention

Thus, in the prior art, device constitution and handling were complex, and miniaturization was difficult. Additionally, for wavelength multiplexing, not only was a large excitation input required, but there was also the disadvantage that the multiplexing degree was low.

The objective of the present invention is to realize a light soliton transmission system and a device therefor with which light soliton pulse signals that have been wavelength-multiplexed are simultaneously amplified with a lower excitation input than that used in conventional soliton amplification using inductive Raman scattering that would have required high induction input, and with which multiple wavelength-multiplexed solitons are regenerated and repeated.

Means to solve the problems

The system of the present invention is characterized in that as erbium-doped single-mode optical fiber is excited with laser light in the 1.4-1.5 μm wavelength, multiple light signals that each have a wavelength of 1.53-1.60 μm, which have different wavelengths from each other and are input to the erbium-doped single-mode optical fiber are amplified simultaneously, are input to a single-mode optical fiber for transmission as a wavelength-multiplexed light soliton pulse train, are propagated in the single-mode optical fiber for transmission, and are regenerated and repeated.

Here, it could also be a system in which output light from multiple DFB semiconductor lasers, the oscillation wavelengths of which are all in the range of 1.53-1.60 μm and which are different from each other, are high-speed modulated or mode matched, and transform-limited wavelength-multiplexed light pulses are input to an erbium-doped single-mode optical fiber as signal light and amplified to the light soliton power level, and are regenerated and repeated.

The device of the present invention is characterized in that it comprises an erbium-doped single-mode optical fiber, an excitation light source that outputs light at a wavelength of 1.4-1.5 μm for exciting the erbium-doped optical fiber, and a means for inputting multiple light signals, each having a unique wavelength between 1.53 and 1.60 μm, to the erbium-doped single-mode optical fiber.

Operation

In the present invention, an Er optical fiber amplifier is excited with semiconductor laser light at a wavelength of 1.40-1.50 μm, light solitons of multiple wavelengths of 1.530-1.560 μm are regenerated and repeated, and wavelength-multiplexed light soliton transmission is realized. The conventional amplification method using inductive Raman scattering depends on nonlinear optical effects of the optical fiber; the present invention essentially differs in that the core of the optical fiber is doped with Er, and a laser medium that can amplify light solitons in the 1.53-1.56 μm wavelength bandwidth is formed beforehand. A fiber length of around 10-30 km is required for soliton amplification using inductive Raman scattering, but in the case of an Er-doped optical fiber amplifier, the fact that a gain of 10 dB or more can be obtained over a length of several meters makes a significant difference. Also, in the case of amplification using inductive Raman scattering, a fiber with small diameter spot size and little optical loss must be used to obtain a gain of around 5 dB; in addition, a higher excitation input of 200 mW or more is required. However, if an Er-doped optical fiber amplifier is used, a high gain of around 10 dB can be obtained with low excitation input of 100 mW or less.

With inductive Raman scattering, in the case of excitation in the 1.46 μm wavelength band, the band is around 20 nm centered at 1.55 μm, but in the present invention, because an Er-doped optical fiber amplifier is used, the band is 40 nm, which is wider, so that wave-multiplexed light soliton communication is possible.

Application examples

Below, application examples of the present invention are explained below with reference to the figures.

Application Example 1

Figure 1 is a figure explaining a first application example of the present invention. In Figure 1, (10) is a light source for exciting the Er-doped optical fiber amplifier. (21), (22), (23), (24), (25), (26) and (27) are light sources for generating light pulses for light solitons wherein the central wavelength of each is displaced 5 nm – 1.530, 1.535, 1.540, 1.545, 1.550, 1.555 and 1.560 μm, respectively. (31), (32), (33), (34), (35), (36) and (37) are optical modulators for optical communication corresponding to each of the wavelengths. (41), 42), (43), (44), (45), (46) and (47) are optical couplers for multiplexing light signals. (11) is an Er fiber for light soliton amplification with an Er-doped core. (12) is a single-mode optical fiber for light soliton transmission. (13) is a multiplexer for multiplexing wavelength-multiplexed signal light with the excitation light for Er light amplification. (51), (52), (53), (54), (55), (56) and (57) are filters for passing only solitons of each signal wavelength. (61), (62), (63), (64), (65), (66) and (67) are the respective light sensors.

To operate the wavelength-multiplexed soliton transmission system in this application example, first, InGaAP semiconductor laser (10) in the 1.4 μm wavelength band, which is the Er fiber excitation light source, is turned on. Next, modulation of the light soliton pulses is performed by optical modulators (31)-(37) for optical communication for the respective wavelengths of light sources (21)-(27) for light soliton pulse generation; the signal light for these seven wavelengths is additionally multiplexed by optical couplers (31)-(37) [sic; (41)-(47)], and wavelength-multiplexed light soliton signals are produced. The wavelength-multiplexed light soliton signals and the output of Er fiber excitation light source (10) are input to Er-doped optical fiber amplifier (11) through optical coupler (13). A gain of around 10 dB over a wavelength range of 1.53-1.56 μm is easily obtained by the Er-doped optical fiber amplifier with an excitation light input power of 100 mW or less, so that by using this, the modulated signal light pulses at each wavelength are amplified to reach an amplitude where they can be transmitted as light solitons in single-mode fiber (12) for light soliton transmission. Wavelength-multiplexed solitons propagated in fiber (12) for light soliton transmission are divided into individual wavelength components in the light-receiving part using filters (51)-(57) that pass only their respective signal light wavelength, and are converted into electrical signals using light sensors (61)-(67).

Various types of optical fibers to which Nd, Pr and the like has been added are known. Of these, in order to amplify light in the 1.530-1.60 μm band, which has the lowest loss, in quartz optical fibers, Er-doped optical fibers are most appropriate. In addition, light at a wavelength of 1.40-1.50 μm is most appropriate for exciting Er. A semiconductor laser that outputs light at any wavelength in this wavelength range can be obtained by changing the InGaAsP composition described above.

As stated above, light solitons can be wavelength-multiplexed and transmitted, and the amount of information that can be transmitted can be dramatically increased. As an example,

communication using $sech^2$ format soliton pulses with pulse width of 1 ps is conceivable. The soliton pulses propagate in the optical fiber while retaining their waveshape. When the pulse repetition rate is set to 10 ps in order to avoid interaction between the light soliton pulses, there is a transmission capacity of 100 Gb/s per wavelength. On the other hand, because transform-limited pulses with 1 ps pulse width have a wavelength halfwidth of 2.5 nm at a wavelength of 1.55 μm, the wavelength interval for wavelength-multiplexed transmission must be 5 nm or more. Here, a transform-limited pulse refers to the fact that the light pulse has no specific form or chirp and that the relationship between pulse width Δt and frequency width $\Delta\nu$ is associated with a precise Fourier transform relationship. For example, in the case of $sech^2$ type pulses, $\Delta\nu\Delta t = 0.32$, and the case of Gauss type pulses, $\Delta\nu\Delta t = 0.44$. In the case of multiplexing of 7 wavelengths in this application example, a ansmission capacity of 7000 Gb/sec is obtained with one optical fiber. With light amplification using inductive Raman scattering used in the prior art, the wavelength bandwidth of the amplifier is around 20 nm, so that the number of wavelengths that can be amplified simultaneously is around 3-4. With the present invention, amplification of solitons over a broad band is possible without using multiple-wavelength excitation light sources. With the Er-doped optical fiber, wavelength-multiplexed solitons can be transmitted over a long distance at intervals every 30 km.

Application Example 2

Figure 2 is a block diagram for explaining a second application example of the present invention. The same components that were used the first application example are represented with the same reference numbers. (71), (72), (73), (74), (75), (76) and (77) are optical fiber couplers for multiplexing the signal light pulse of each wavelength with the excitation light for the Er-doped optical fiber amplifier. (81), (82), (83), (84), (85), (86) and (87) are DFB (distributed feedback) semiconductor lasers with wavelengths of 1.530, 1.535, 1.540, 1.545, 1.550, 1.555 and 1.560 μm, respectively.

DFB lasers (81)-(87) are operated to oscillate continuously, and the output is high-speed modulated by optical modulators (31)-(37). A Mach-Zehnder waveguide modulator using $LiNbO_3$, for example, is used as the optical modulator. The modulated signals and excitation light are multiplexed by optical fiber couplers (71)-(77) and coupled to Er-doped optical fiber amplifier (11), and the signal light pulses are amplified to an amplitude which is in the soliton region.

By using an optical fiber coupler as a multiplexer, wavelength multiplexing can be realized by fusing together the ends of the optical fibers constituting each of the optical fiber couplers. In this way, compared to when a semitransparent mirror and a dichroic mirror are used, the insertion loss of optical components for coupling, e.g., lenses, can be significantly reduced. The result of this is that it is not necessary to make the gain of Er-doped optical fiber amplifier (11) very high,

and light solitons can be propagated in single-mode optical fiber (12) with relatively low excitation input. And because transform limited pulses can be obtained by combining DFB lasers and external modulators, it is possible to suppress waveform deterioration when pulses are propagated over long distances. Therefore, by using an Er-doped optical fiber amplifier to compensate for losses from optical fiber (12) for light soliton transmission, transmission of wavelength-multiplexed light solitons over long distances is possible.

Application Example 3

Figure 3 is a block diagram for explaining a third application example of the present invention. The same components that were used in the first application example are indicated by the same reference numbers. (91)-(97) are mode-matched DFB lasers, and the oscillation wavelengths are 1.530, 1.535, 1.540, 1.545, 1.550, 1.555 and 1.560 μm, respectively. Mode synchronization of the DFB lasers can be realized by attaching an external resonator to the laser and using an optical modulator placed in the resonator, for example. Transform-limited pulse trains wherein the pulse repetition rate is determined by the resonator length are generated from mode-matched DFB lasers (91)-(97). The pulse trains are modulated by optical modulators (31)-(37), and a signal pulse train is produced. The modulated light signals and laser light for Er fiber excitation are multiplexed and coupled to Er-doped optical fiber (11) by optical fiber couplers (81)-(87), and the signal light pulses are amplified to an amplitude which is in the light soliton region.

Transform-limited pulse trains can easily be generated by using mode synchronization, so that by placing an Er-doped optical fiber amplifier (11) every 30 km, for example, and compensating for optical losses from optical fiber (12) for light soliton transmission, wavelength-multiplexed solitons can be transmitted over long distances of 1000 km or more.

Effects of the invention

As explained above, the present invention has the advantage that wavelength-multiplexed soliton pulse trains can be amplified at the same time by inserting an Er-doped optical fiber amplifier that is excited by a semiconductor laser having an oscillation wavelength at 1.4-1.5 μm into the transmission path, so that the pulse trains can be transmitted over long distances. This optical fiber amplifier also uses a semiconductor laser with relatively low output for excitation, and has gain in the wavelength range of 1.53-1.56 μm, based on the principle of producing a population inversion in the amplifying optical fiber and performing amplification. Thus, it has the advantage of being able to realize an amplifier that has high gain, is small and has a wide wavelength range. Super high-speed optical communication of several hundred Gb/s or more can be realized with the present invention.

Brief description of the figures

Figure 1 is a block diagram for explaining a first application example of the transmission method and device in the present invention,

Figure 2 is a block diagram for explaining a second application example of the present invention,

Figure 3 is a block diagram for explaining a third application example of the present invention,

Figure 4 is a block diagram for explaining a conventional light soliton transmission system,

And Figure 5 is a block diagram for explaining a light amplification method using inductive Raman scattering.

10	Light source for Er-doped optical fiber amplifier excitation
11	Er-doped optical fiber for light soliton amplification
12	Single-mode optical fiber for light soliton transmission
13	Multiplexer
14	Excitation light source for Raman amplification
15	Raman amplifying optical fiber
21-27	Pulsed light source for light solitons
31-37	Optical modulator for optical communication
41-47	Optical coupler
51-57	Wavelength separating filter
61-67	Optical sensor
71-77	Optical fiber coupler
81-87	DFB semiconductor laser
91-97	Mode synchronized DFB laser

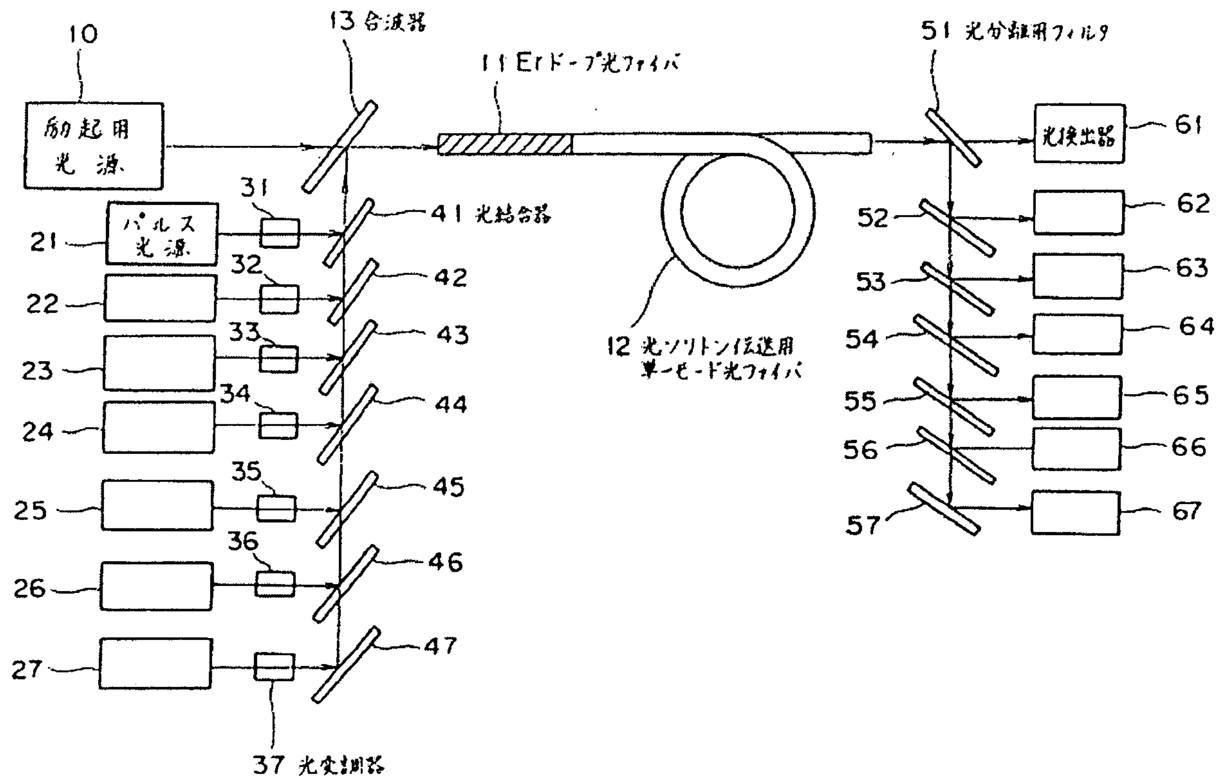

Figure 1. Block diagram of first application example of present invention

Key:

Key:	10	Excitation light source
	11	Er-doped optical fiber
	12	Single-mode optical fiber for light soliton transmission
	13	Multiplexer
	21	Pulsed light source
	37	Optical modulator
	41	Optical coupler
	51	Light separating filter
	61	Optical sensor

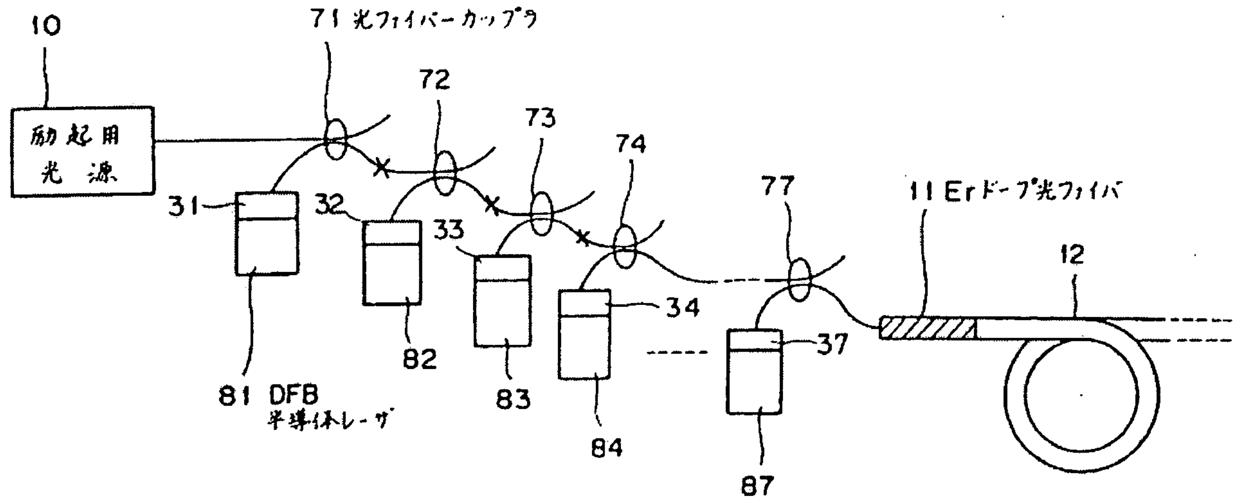

Figure 2. Block diagram of second application example

Key: 10 Excitation light source
11 Er-doped optical fiber
71 Optical fiber coupler
81 DFB semiconductor laser

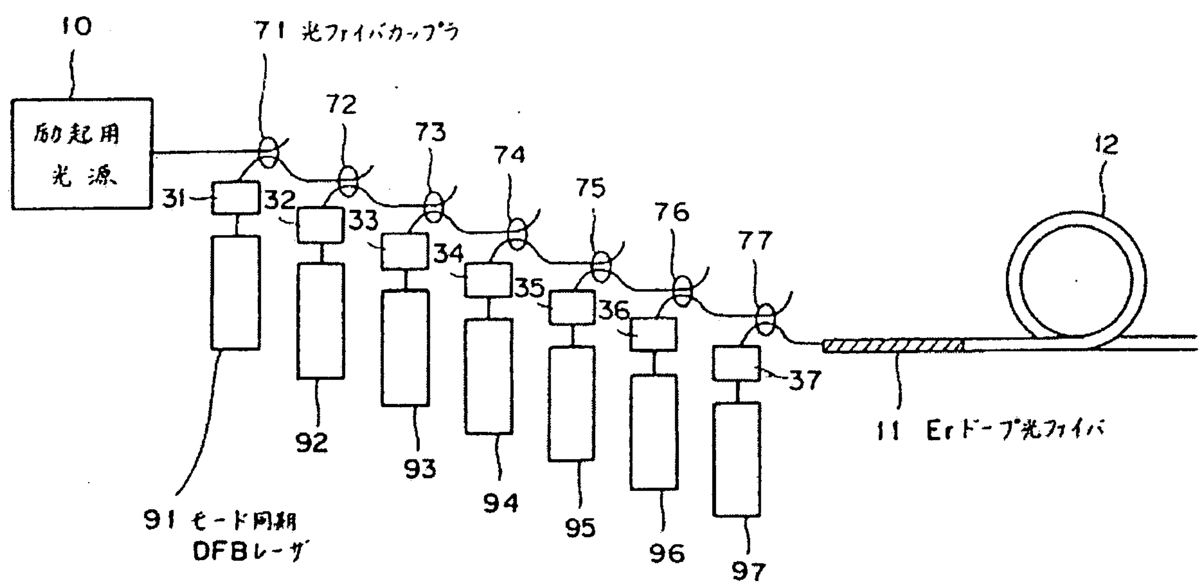

Figure 3. Block diagram of third application example

Key: 10 Excitation light source
11 Er-doped optical fiber
71 Optical fiber coupler

91 Mode synchronized DFB laser

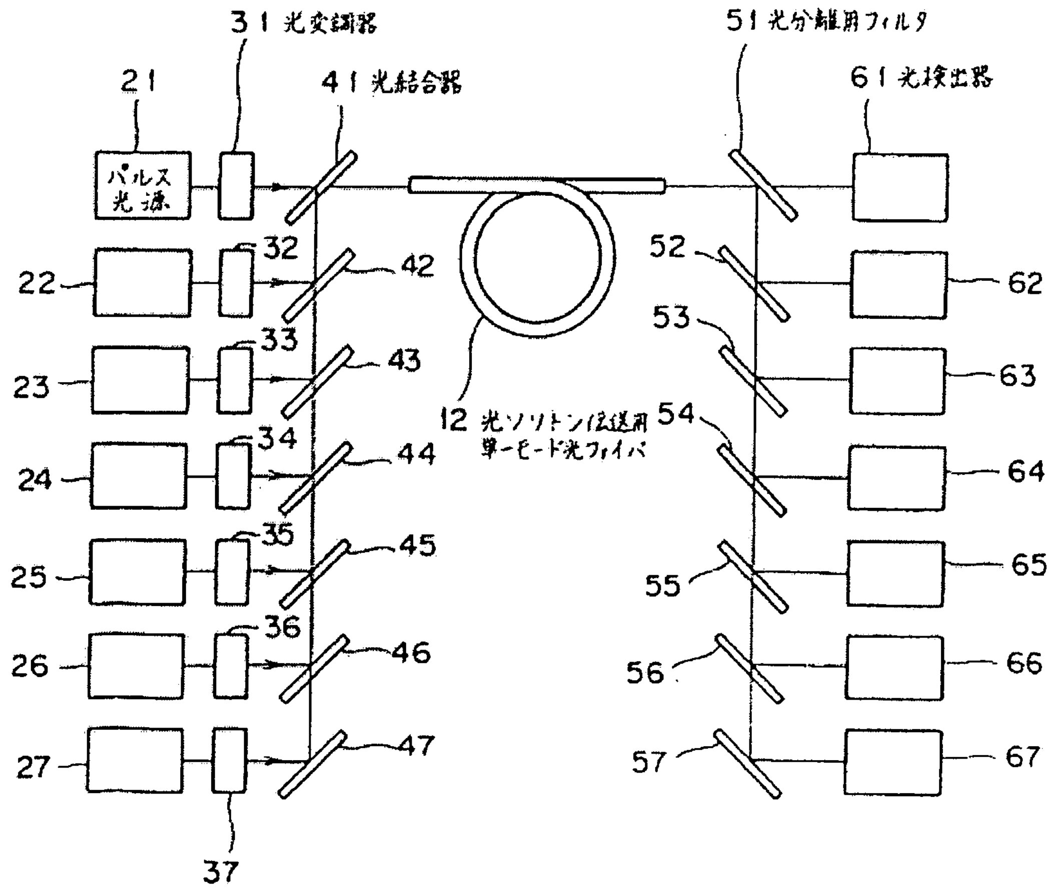

Figure 4. Block diagram of conventional light soliton transmission system

Key:

Key:	12	Single-mode optical fiber for light soliton transmission
	21	Pulsed light source
	31	Optical modulator
	41	Optical coupler
	51	Light separating filter
	61	Optical sensor

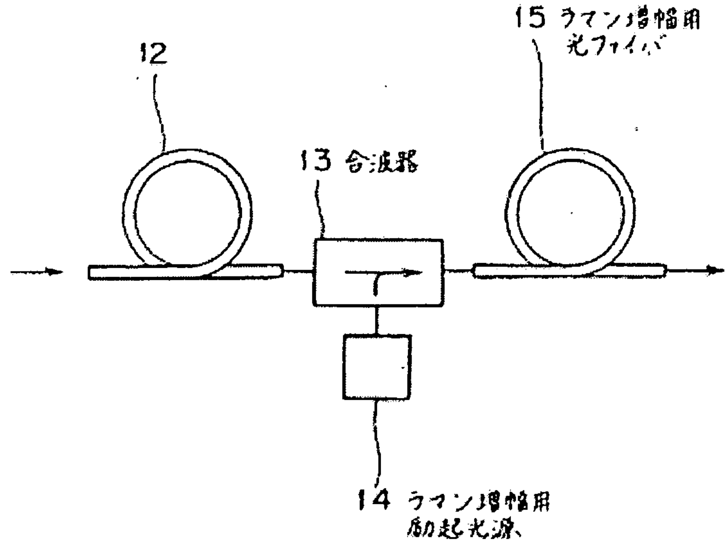

Figure 5. Block diagram of light amplification using inductive Raman scattering

Key:
- 13 Multiplexer
- 14 Excitation light source for Raman amplification
- 15 Raman amplifying optical fiber